Ensuring Sustainable Development via Groundwater Management (Case Study: El Bahariya Oasis)

Mohamed Fahmy M. El Hossary

Associate Professor, Desert Research Department, Research Institute for Groundwater, National Water Research Center, Egypt. Melhossary62@Ymail.Com

Abstract: In this research, an attempt was made to develop and test water management scenarios in Bahariya Oasis which is one of the promising oases in the Western Desert. Groundwater potential, for future development, is assessed, based on available data and information. A simulation was made for the present trends in groundwater heads as the base for testing the impacts of future developments. The results indicated that even under the high water allocation per feddan, the expected drawdowns are still in the safe range. The results, also, outlined that the maximum expected drawdowns will range between 3 and 26 meters for the minimum water allocation after 25 years (i.e. which represents less than 10 % of the saturated thickness between 32 and 4 meters after 50 years). It was also clear that the additional expected cultivated area will be about 50 thousand feddans. It was further recommended to discuss the results with the local people and developers, to implement the proposed scenarios on a gradual basis with appropriate monitoring of impacts, to compare the results of monitoring with the obtained simulation results and to revise the scenarios based on the results.

[Mohamed Fahmy M. El Hossary. **Ensuring Sustainable Development via Groundwater Management (Case Study: El Bahariya Oasis).** *J Am Sci* 2013;9(6):6-13]. (ISSN: 1545-1003). http://www.jofamericanscience.org. 2

Keywords: Bahariya Oasis, Groundwater Management, Sustainable Development, Nubian Sandstone Aquifer System**.**

1. Introduction

Egypt is suffering from poor distribution of population over the geographic area in addition to continuous urbanization of the most productive lands in the Nile Delta and Valley. One of the reasons is the unavailability of water resources in the vast deserts. This dictates development of appropriate strategies for the management of groundwater, being the sole source of water, in the vast deserts.

This research was thus initiated with the objective of attempting to develop and test water management scenarios for Bahariya Oasis, which is one of the promising oases in the Western Desert, figure (1).

The sole water source water in the oasis is groundwater from the Nubian Sandstone Aquifer System which is non-renewable. The aquifer system is generally not homogeneous due to the existence of impermeable shale beds subdividing the aquifer into a number of interconnected aquifers. The present developments are conducted by locals as well as large investors.

This paper introduces the research phases under the following headlines:

- Describing the hydrological setting of the study area
- Outlining the historical development of study area
- Executing numerical simulations
- Analyzing and presenting the results

2. Describing Study Area Hydrological Setting

Bahariya Oasis is bounded by latitudes 27o 45\ N to 28o 30\ N and 28o 30\ E to 29o 13\ E. It is located at about 360 km southwest of Cairo. It covers a physical area of about 2000 km2. The only source of freshwater in the study area is groundwater from the Nubian Sandstone Aquifer (bulk thickness ± 2000 m, salinity in terms TDS = 250 ppm) which is non-renewable.

The aquifer system consists generally of two zones, separated by impervious shale layers, (Figures 2a, 2b and 2c).

The saturated thickness of the shallow (phreatic) aquifer ranges between 200 and 250 meters; whereas that of the deep (confined) aquifer varies between 1,000 and 1,600 meters. The two aquifer zones are separated by a shaly-clay layer ranging in thickness between 300 m and 400 m. Due to the presence of faults, both aquifers can be considered hydraulically interconnected.

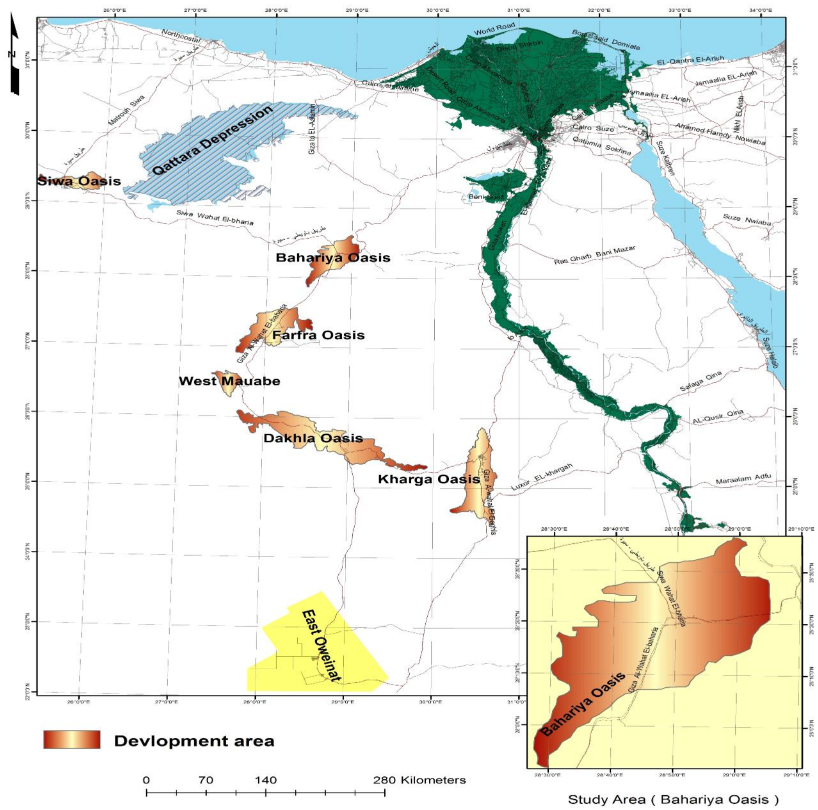
3. Outlining the Historical Development of Study Area

Groundwater from the Nubian Aquifer System has been utilized since centuries in the Oases of the Western Desert through springs and hand-dug wells. Since 1960 deep wells have been initiated by the government to satisfy large scale development in almost all the oases of the Western Desert (Kharga, Dakhla, Bahariya and Farafra) in 1990 in Siwa Oasis and East Oweinat areas, and lately in Darb El-Arbain area.

At present, a combination of shallow and deep wells exists (up to 1,000 meters) in addition to few springs taping the Nubian Aquifer System along subsurface fault planes. The use of groundwater from these wells and springs is limited mainly to the agriculture activities and a few of them for drinking purposes for the local people.

The recharge sources for the Nubian Aquifer System is mainly from the southern mountainous areas (Ennedi and Tibesti) where the precipitation during the past pluvial periods.

Before 1963, groundwater extraction in Bahariya Oasis was obtained from 332 natural springs and shallow dug wells at a rate of 33 mcm/year. During the period 1963-1998, large development took place; thus increasing the total extraction to about 90 mcm/year by the end of the period. Table (1) summarizes the present extraction rate according to last survey (RIGW, 2010).



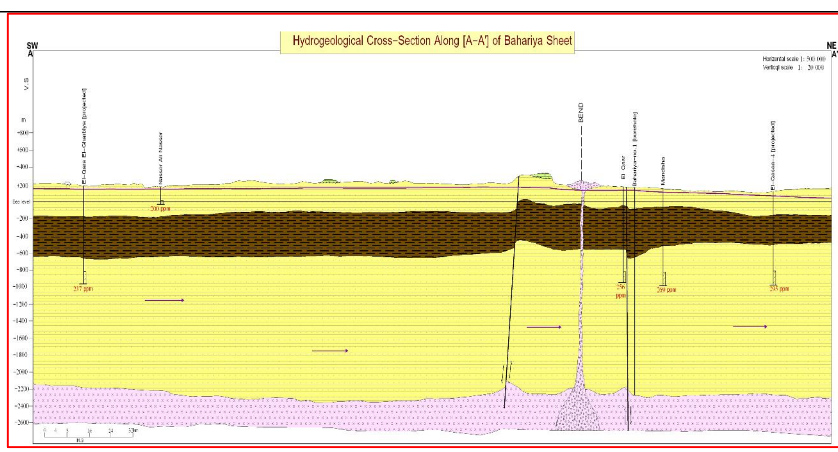


Figure (2a) Hydrogeological cross section at El Bahariya area

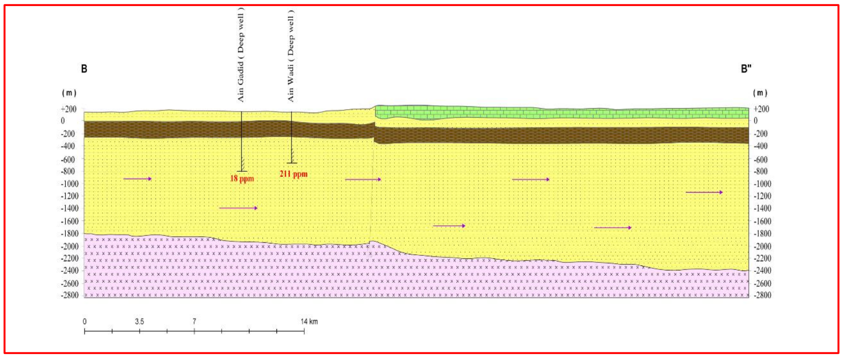


Figure (2b) Hydrogeological cross section at Gabal Ghoraby area

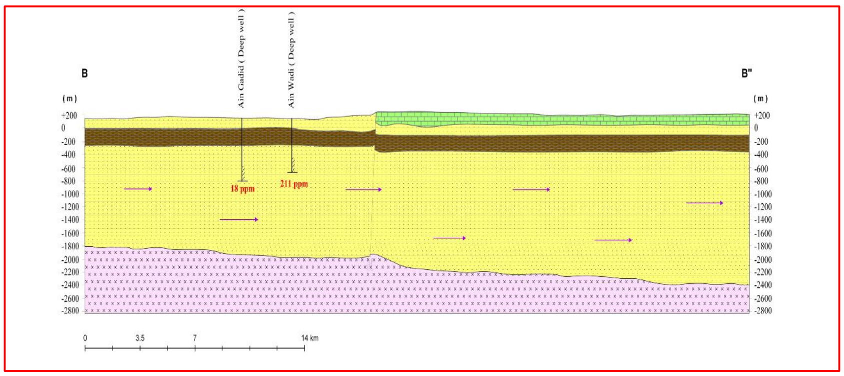


Figure (2c) Hydrogeological cross section at Ain Khoman area

Table (1): Daily and Annual extraction from shallow and deep wells (RIGW 2010)

	Shallow wells		Deep wells		Cultivated area (feddans)	Total extraction **m^3/d**	Total extraction **m^3/y**
	< 300 m depth		> 700 m depth				
	No. of wells	Q m^3/d	No. of wells	Q m^3/d			
El Bahariya area	636	139221	80	144482	12,723	283,730	85,119,000
Gabal Ghoraby area	146	17088	13	25680	2,690	42,768	12,830,400
Ain Khoman area	29	5080	1	2400	278	7480	2,244,000
Total	811	161,389	94	172,562	15,691	333,978	100,193,400

4. Executing Numerical Simulations

The easiest way to reach a solution to mining is to execute a numerical simulation to examine different scenarios. This is attributed to the fact that groundwater mining refers only to the depletion of a stock of non-renewable groundwater. However, planned mining of an aquifer system could be considered a strategic management option if the full physical, social and economic implications are understood and accounted for over time. These characteristics apply to the Nubian Aquifer System, and thus the future development must be based on accurate estimates of the groundwater potential, taking into consideration extending the life time of the water in stock. This can better be tested on a simulation model that describes the physical conditions of the system.

4.A Simulation Of Initial Conditions

The mathematical package used to simulate groundwater flow in the area is Visual Modflow. Bahariya Oasis is divided into 3 sub-areas: El Bahariya area, Gabal Ghoraby area and Ain Khoman area, (Figure 3). Data and information necessary to prepare the model are assembled from the field and other administrative institutions. The area is covered by a network of grids consisting of 111 rows and 97 columns (cell area 1000 x 1000 meters) and three main layers in the vertical direction (the shallow zone of Nubian aquifer, the second is impermeable layer of thickness 300 - 400 m; and the third layer is the deep aquifer zone of the Nubian aquifer).

Input data included the hydraulic parameters (hydraulic conductivity and specific storage) obtained from pumping tests, geological studies and geophysical logs, as follows:

1) The aquifer hydraulic conductivity ranges between 4 and 20 m/day

2) The transmissivity varies between 250 and 3700 m2/day
3) The storage coefficient varies between 0.8 x 10-1.and 10-3

The model was run under steady state conditions (considering extraction rate in 1980) and in the transient case (extraction changing with time till the year 2010 which is 100 mcm/year).

Calibration was made against groundwater heads obtained from the piezometers at El Bahariya Oasis. Figure (4) shows the results of the calibrated model.

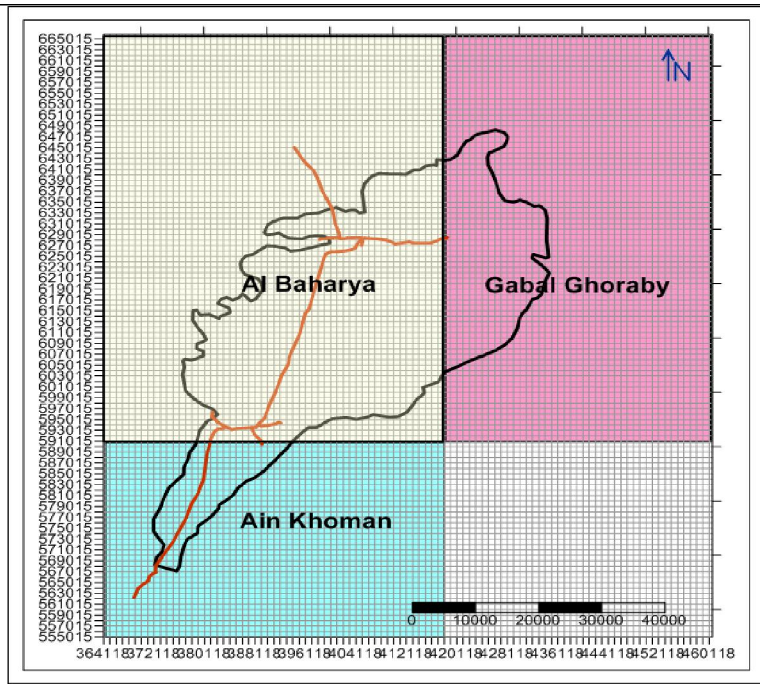


Figure (3) Model Grid of Bahariya Oasis sub-areas

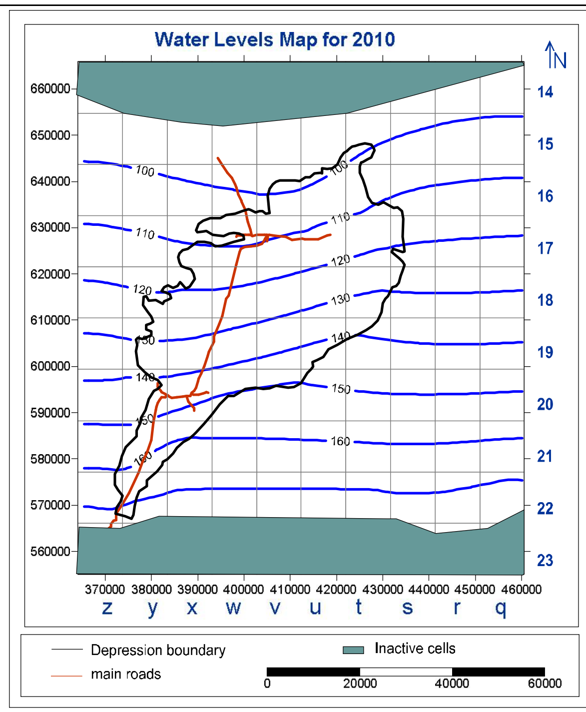


Figure (4) Water level map for year 2010 as model out put

4.B Development and Testing 0f Future Scenarios

The residual groundwater potential is estimated as 50 % of the saturated thickness of the deep aquifer as determined from the monitoring data, (Table 2).

Assuming water allocation per feddan to range between 15 and 20 cum/day, based on the irrigation system and the crop, expected drawdowns were estimated for the three sub-areas.

5. Analyzing and Presenting the Simulation Results

The results were obtained, analyzed and are presented here. Figures (5) to (10) illustrate the expected drawdowns for each allocation scenarios in the three sub-areas. They indicate that:

- Even under the high water allocation per feddan, the expected drawdowns are still in the safe range.
- The maximum expected drawdowns will range between 3 and 26 meters for the minimum water allocation after 25 years which represent less than 10% of the saturated thickness; between 32 and 4 meters after 50 years
- The additional expected cultivated area will be about 50 thousand feddans at the three sub-areas.

Table (2) Drawdown results from the model due to additional future extraction compared with saturated thickness of the deep aquifer

	Residual groundwater potential (1000 m3/y)	Saturated thickness (m)	Water allocate m3/d/fed	Additional future Extraction m3/d	D.D (m) After 25 year	D.D (m) After 50 year	Cult. Area (fed)
Bahariya Area	228700	1600	20	651640	26	32	32000
			15	488730	20	25	42582
Gabal Ghoraby Area	60000	1600	20	151380	12	17	8870
			15	113535	10	15	11770
Ain Khoman Area	12750	700 -1000	20	80000	5	7	4000
			15	60000	3	4	4000
Total	301450						

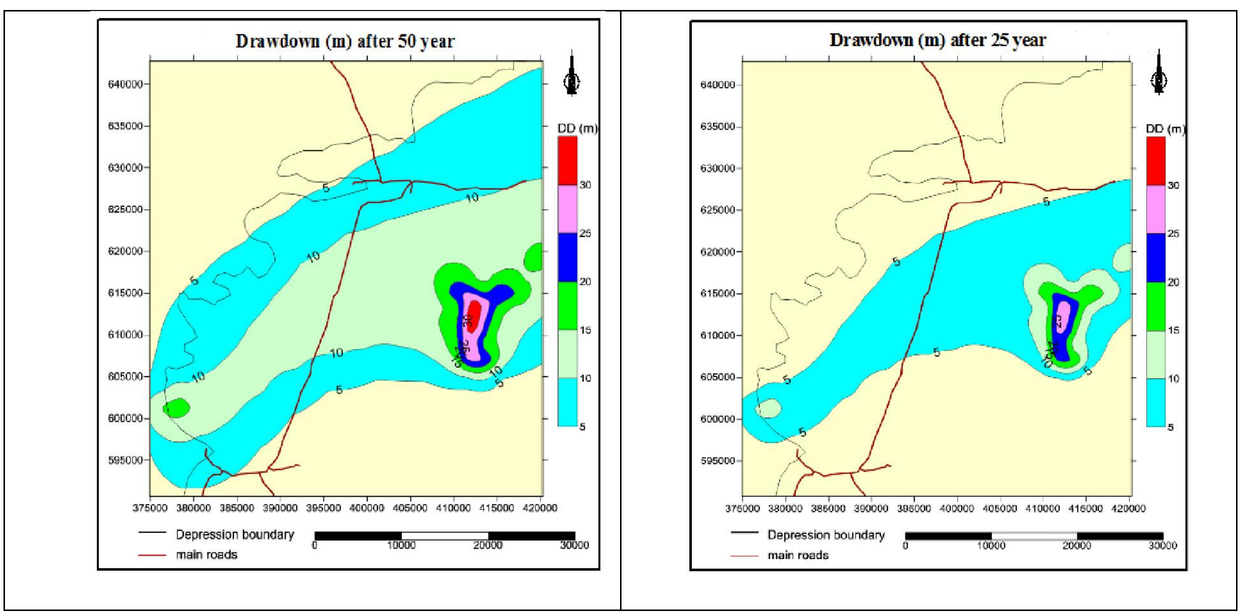


Figure (5) Drawdown (m) at el Bahariya area after 25 and 50 year (allocated water 20 m^3/day/feddan)

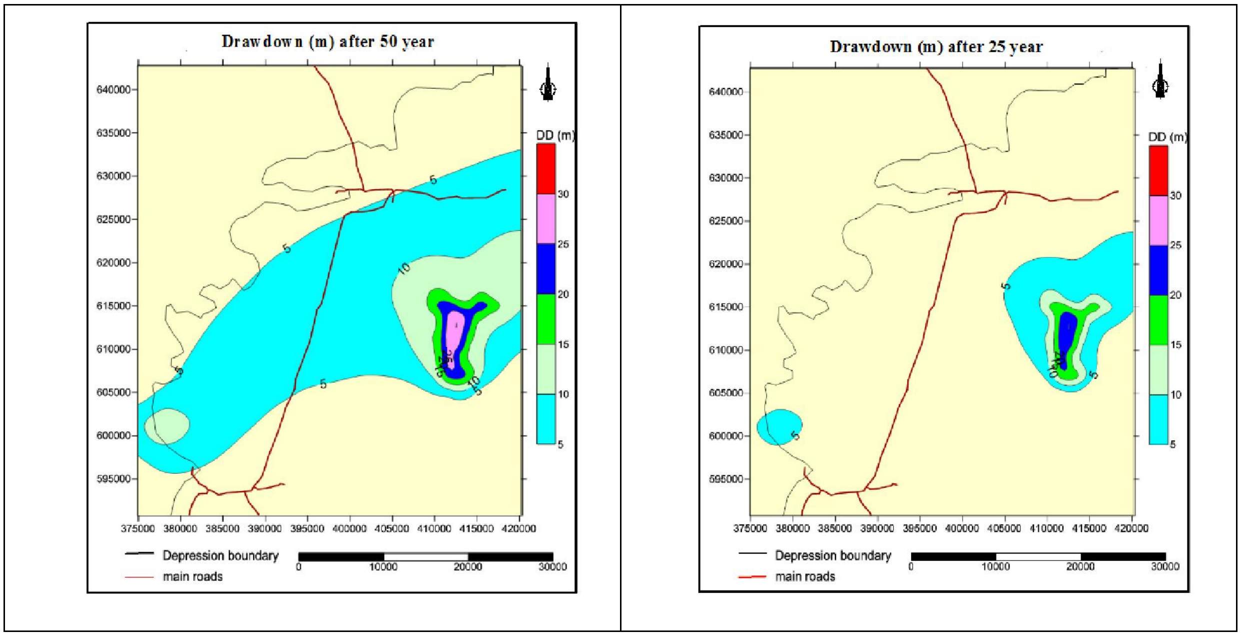


Figure (6) Drawdown (m) at el Bahariya area after 25 and 50 year (allocated water 15 m^3/day/feddan)

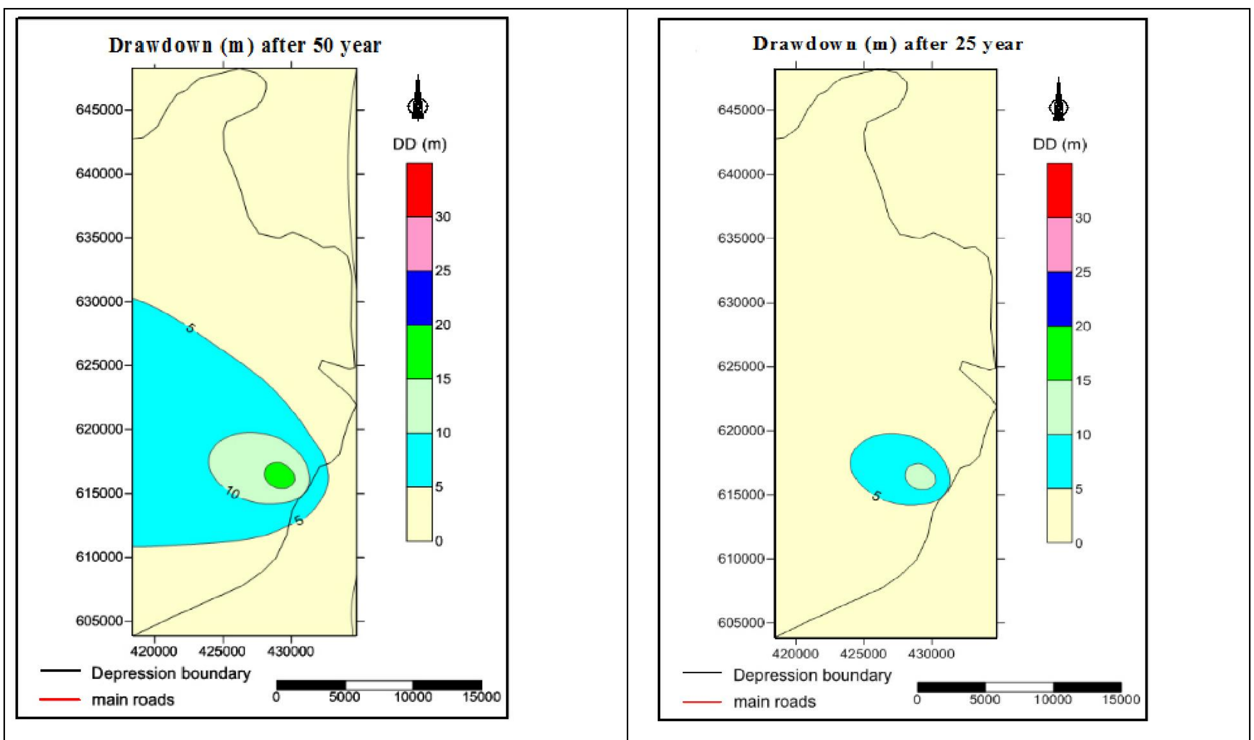


Figure (7) Drawdown (m) at Gabal Ghoraby area after 25 and 50 year/ allocated water 20 m^3/day/feddan

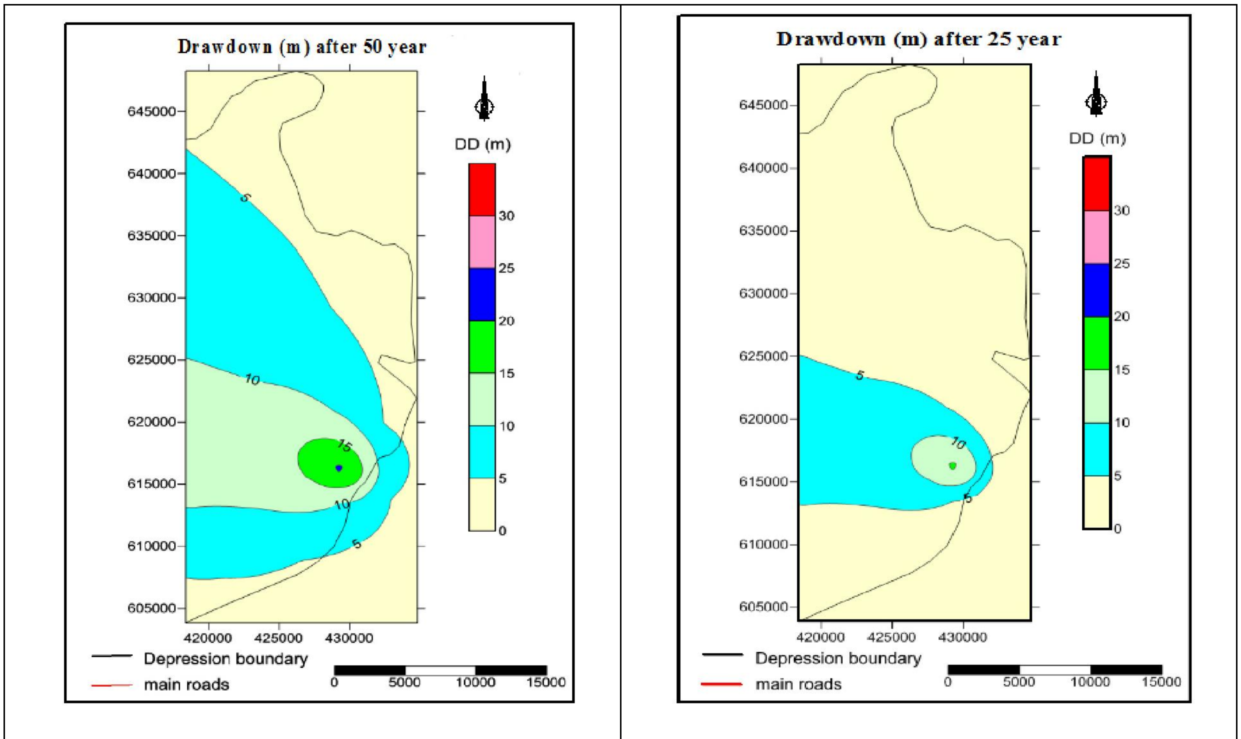


Figure (8) Drawdown (m) at Gabal Ghoraby area after 25 and 50 year (allocated water 15 m^3/day/feddan)

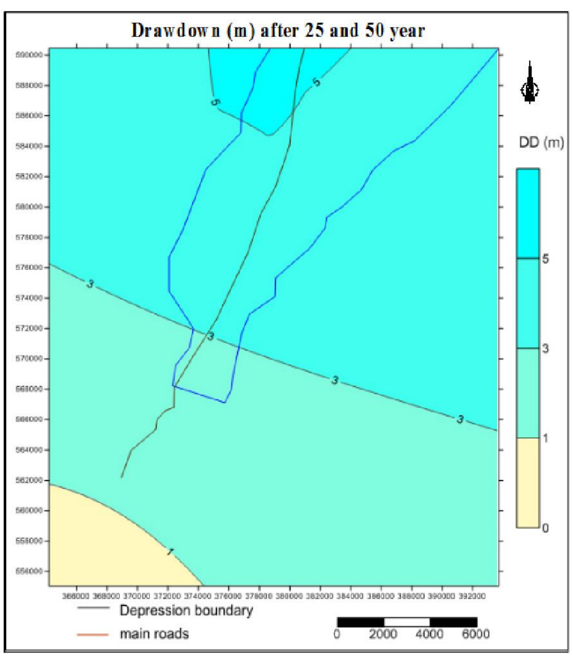


Figure (9) Drawdown (m) at Ain Khoman area after 25 and 50 year/ allocated water 20 m^3/day/feddan

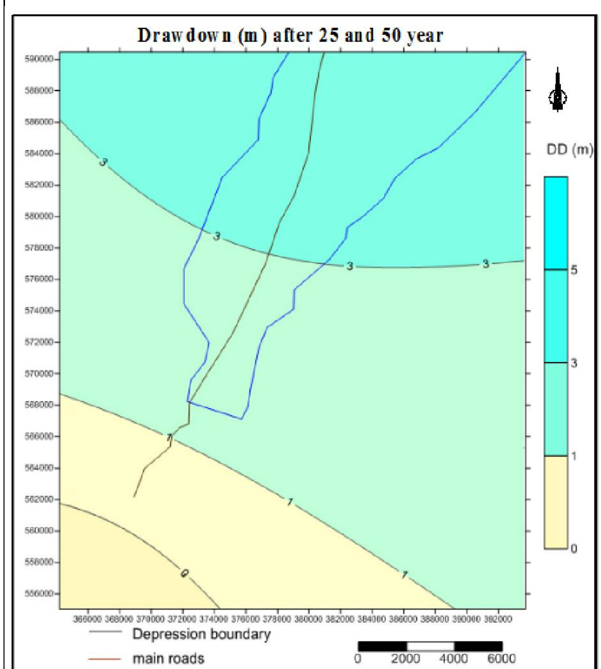


Figure (10) Drawdown (m) of water level at Ain Khoman area after 25 and 50 year (allocated water 15 m^3/day/feddan)

6. Conclusions and Recommendations

In this research, an attempt was made to develop and test water management scenarios for the Bahariya Oasis. The results indicated that:

- Even under the high water allocation per feddan, the expected drawdowns are still in the safe range.
- The maximum expected drawdowns will range between 3 and 26 meters for the minimum water allocation after 25 years which represent less than 10% of the saturated thickness; between 32 and 4 meters after 50 years.
- The additional expected cultivated area will be about 50 thousand feddans.

Since the previous results have been based on simulation of present hydrogeological conditions with almost no consideration of human behavior. Therefore, it is highly recommended to:

- Discuss the results with the local people and developers.
- Implement the proposed scenarios on a gradual basis with appropriate monitoring of impacts.
- Compare the results of monitoring with the obtained simulation results.
- Revise the scenarios based on the results.

Acknowledgments

This research was supported by Groundwater Modeling Research Unit, Research Institute for Groundwater (RIGW).

4/29/2013

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